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PROJECT DESCRIPTION:

Design, Build and operate of a Mechanical and Biological Waste Treatment Plant in the North of Malta

CLIENT:

CONSORTIUM:

BTA International

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VASSALLO BUILDERS LIMITED

B.E.V. Consortium

PARTICIPANT:

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PROCESS DESCRIPTION DESIGN

Contents

1 Introduction

This process description shall give an overview of the different treatment steps, their final products and the interconnection between the single steps and aggregates.

2 Dry Pre-treatment and Sorting

The process description of this system is described in the document registered in Aconex with the number EFAE-MT-MEC-EQP-DSM-0001 - Mechanical Dry Treatment - Base Design.

The following paragraph substitutes the paragraph with the same number of the document EFAE-MT-MEC-EQP-DSM-0001 - Mechanical Dry Treatment - Base Design.

After bales are fully tied with the straps, the bales are fed to the wrapper via the bale track mounted between the baler and the wrapper. After this, the bale is pushed by one other bale to the wrapper front conveyor. This conveyor has the advantage of allowing for bales to build up on top of it in case of wrapper downtime, even though the baler press may still be fully operational and producing bales.

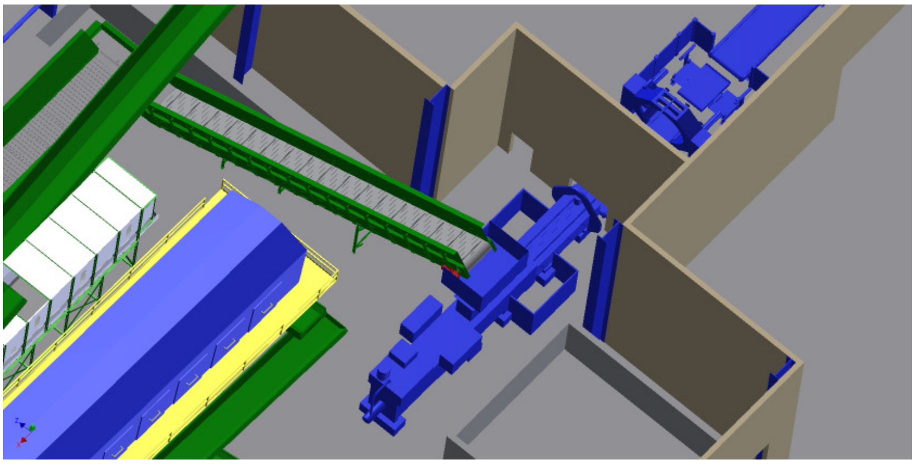


Figure 1 – Wrapper feeding system

This feeding conveyor then feeds the wrapping unit itself, where the wrapping begins, just after the incoming sensor detects that the bale has reached to the unit.

After the wrapping is finished, the wrapped bale is placed on top of the rear conveyor (see image 13).

The characteristics of the wrapper should be approximately as follows:

Image 1 – Wrapper

- At the end of the wrapping process the bale is wrapped with stretch film on all six sides tightly
- To effectively wrap on all six sides, the bale is rotated along two axis
- The rotations of the bale are exact and more film can be added in all corners to ensure the correct and necessary amount of plastic film around the bale, particularly around the corners
- Each bale wrapping takes less than sixty seconds by wrapping it simultaneously through both axes, thereby improving efficiency, tightness of the bales, and productivity as the total bale wrapping time is minimized
- Two axis wrapping system also results in a significant reduction of the energy required, of the amount of plastic film required and of the amount of wear and tear
- When the incoming bale reaches to the income wrapper sensor the automatic wrapping begins
- There are several (four) pre-programmed programs that can be selected to wrap the bales, according the customer's wishes
- The unit is designed to be installed directly after the multi-material baler press
- A proofed and very reliable conveyor belt transports the bale into the wrapper (front conveyor). During the transport the length of the bale is taken and the wrapping process immediately and automatically begins. The wrapping begins around the bale horizontal axis, after which the bale is positioned in the middle of the rotation table, where the bale is then rotat-

ed around is vertical axis and simultaneously wrapped by the swinging arm, covering all the corners and sides with 750mm plastic film. The stretched film is immediately supporting wires, not needing extra added strengthening

- The monitoring operation is constantly monitored by a Film Break Control System (film watch). In the event of a film breakage on one of the rolls, or if one of the roll runs out, the machine will automatically switch to “single roll” mode of operation to finish the wrapping, maximizing production and minimizing downtime by eliminating the need to stop the wrapping process due to a single breakage. In the unlikely event of both film rolls breaking, the machine shall stop the bale wrapping process until the problem is rectified
- An intelligent bale handling system does control the speed and rotation of the bale to ensure that the wrapping arms are able to apply the film correctly to all areas, including the corners and ends of the bale. In addition, the unit allows for adjustments to be made to the amount of overlap between layers, as well as the total number of layers, thereby allowing the bale wrapping procedure to be optimized to suit specific conditions and requirements
- The wrapping machine allows wrap bales from 700x700x800 mm to 1400x1200x2000 and bales weights up to 3000 kg. The length of the bale can be varied between 700 to 2000 mm. For handling facility and calculations, it was considered bales with 1200x1100x750 mm.
- Once the wrapping procedure is complete, the plastic film is automatically connected to the next bale, without the delay of cutting and holding. The film cutting procedure occurs automatically as the already wrapped bale is conveyed forward
- The wrapped bale is automatically transported out of the wrapping section onto the storage conveyor, from where a crane (or fork lift) shall pick up the bale and transport it the storage area
- The whole process of bale transport is made through conveyors so that no damage is done on the unwrapped bale and afterwards, on the wrapped bale.

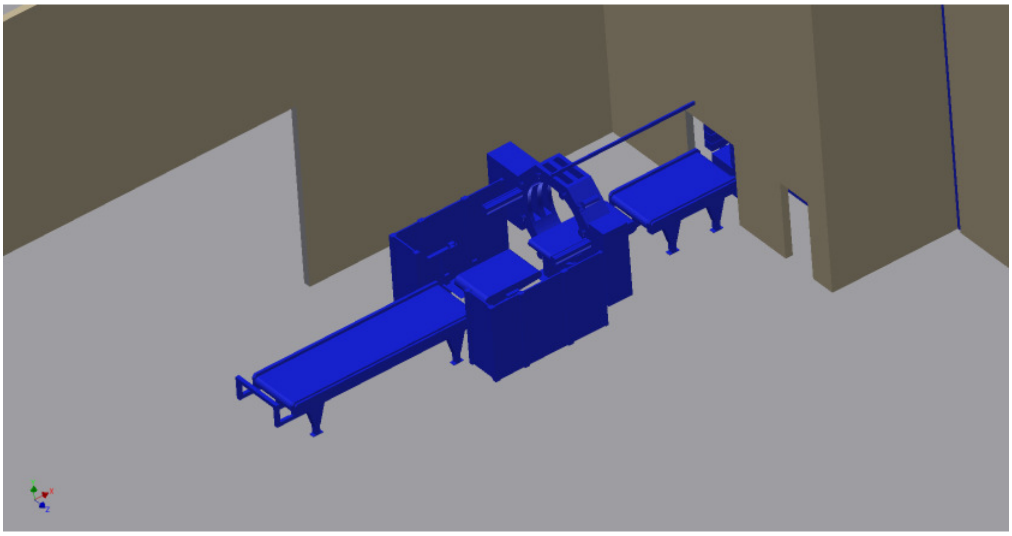


Figure 2 – Wrapper (101AK002)

After wrapping the bales of paper/cardboard, plastics and RDF they will be transported by a crane installed outside of the mechanical dry treatment building. This crane will be responsible for transporting the bales to the RDF loading bay whose storage capacity is about 400 bales. One other possibility is to load the trucks directly with the crane (see attached drawing: EFAE-MT-CIV-INS-DWG-0001).

The daily number of bales is about 195 units:

- Bales of RDF: approximately 160 units
- Bales of Plastics: approximately 15 units
- Bales of Paper/Cardboard: approximately 20 units

The crane shall be provided with a device for lifting bales without damaging them (see example in the following Image 2).

Image 2 – System for lifting bales

The bales that are transported to the RDF storage location will be organized by type with the support of a forklift. The capacity of this area is about 7295 bales (see attached drawing: EFAE-MT-CIV-INS-DWG-0001 and calculation on EFAE-MT-PRC-MBL-CAL-0001).

The forklift supplied by the client must have a bale clamp, like the one presented in the Image 3.

Image 3 – The bale clamp

Advantages of this accessory:

- Easy to use.
- Powerful double effect cylinder allows the manipulation of heavy bales;
- Articulated clamp designed to fit the shape of every bale;
- Smooth structure that avoids perforation of plastic film.

After the approval of the document EFAE-MT-MEC-EQP-DSM-0001 - Mechanical Dry Treatment - Base Design, Efacec will update the document with a new revisions already with the change of this paragraph an following attachments.

EFAE-MT-CIV-INS-DWG-0001 (Revision B)

EFAE-MT-PRC-MBL-CAL-0001 (Revision B)

3 Wet Pre-treatment of Organic Fraction Municipal Solid Waste

3.1 Pulper feeding system

The organic matter recovered in the dry pre-treatment is the input and thus the starting point for the BTA® Hydormechanical Pre-treatment, in special for the BTA® Waste Pulpers. While the operation of the equipments of the dry pre-treatment is continuous over the operation time, the pulpers operate batchwise. For this reason, it is necessary to foresee an intermediate buffer (102AT004) to bridge this difference in the operation modus. A cascade of feeding conveyors (102AF008-013) allows to feed each Pulper (or – in case it should be necessary - to completely bypass them by putting the organic matter on the light fraction conveyor 115AF001).

The pulper feeding conveyor 1 is equipped with a balance system to measure the input to the pulpers.

3.2 BTA® Hydromechanical Pre-treatment

The BTA® Hydormechanical Pre-treatment consist of two steps:

- Dissolution and defibring of the digestible organics into an organic suspension and and removal of coarse impurities in the BTA® Waste Pulper
- Removal of fine impurities in the BTA® Grit Removal System

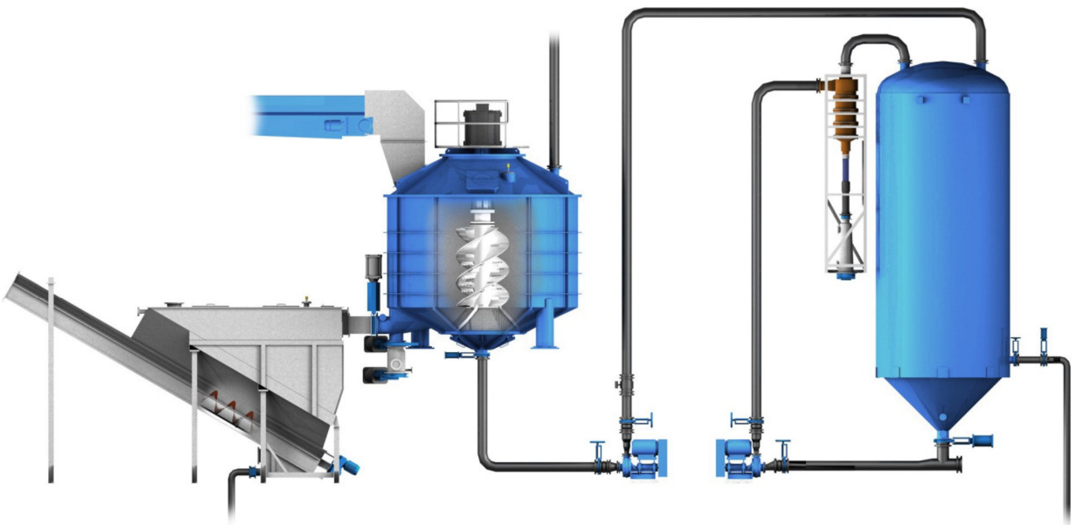


Fig.3.1: Schedule of the hydromechanical pretreatment / simplified (for BTA Waste Pulper with LRS Rake)

In the following pages, the Hydromechanical Pre-treatment in the BTA® Waste Pulper is described.

Pulping is performed to facilitate three objectives:

- Disintegration of biodegradable waste to enhance the subsequent digestion process
- Removal of non-biodegradable contaminants as a "heavy" fraction (stones, large bones, batteries and metallic objects)
- Removal of non-biodegradable contaminants as a "light" fraction (textiles, wood, plastic film, string etc)

In the BTA® Waste Pulpers (111AT001, 112AT001 and 113AT001), process water is added to the waste, which produces a suspension with a water content of approx. 90 weight-percent. The suspension is pumpable and mixable and thus easy to handle in terms of process technique.

The BTA® Waste Pulper is operated in batch-mode. This batch-mode consists basically of the following operation steps:

- charging of the Pulper
- dissolving process (defibration of the biowaste)
- pumping out of the biowaste-suspension
- filling with process water
- heavy fraction discharge and
- light fraction removal

Fig. 3.3. BTA® Waste Pulper with LRS Screw in Manchester, UK

In function of the waste composition it is possible / necessary to foresee a second dissolving step.

The charging of the BTA® Waste Pulper is controlled by a specially developed automation system. Once the desired concentration of solids in the Pulper has been reached, the charging with waste is stopped automatically.

The BTA® Waste Pulper is equipped with a special turbine. When it rotates, fluidic forces defibrate, suspend and partly dissolve the digestible organic fraction contained in the waste. Biologically non-degradable substances, such as plastics, textiles, metals, glass etc. are not damaged in the process. These contaminants are separated at the end of the treatment cycle (Grit Removal System).

After the dissolving process the waste-suspension is extracted through a sieve plate with a perforation limit of 10 mm at the bottom of each Pulper by means of thePulper Discharge Pump (111AP001, 112AP001, 113AP001). It has a dry substance of approx. 10 weight %.

Before the discharge of the contaminants the Pulper is filled with process water 0/1. The contaminants retained in the Pulper are now separated from the mixture of process water and contaminants on the basis of their different sedimentation characteristics.

At the bottom of the Pulper the heavy fraction (glass, sand, stones, batteries, metals etc.) sediments and is removed by means of a trap system from the mixture of process water and contaminants. Before discharge it is rinsed with process water to minimize the remaining content of residual organic substances. With a dewatering screw conveyor (Heavy Fraction Screws 1 – 6; 111AT002, 111AT003, 112AT002, 112AT003, 113AT002, 113AT003) the purified heavy fraction is further rid of fine organic particles, then dewatered and transferred to the Heavy Fraction Conveyor 1 (110AF001), Heavy Fraction Conveyor 2 (110AF002) and the Heavy Fraction Container 1 and 2 (110BB101, 110BB102).

The light fraction (plastics, textiles, composite materials as well as the hardly or non-digestible organic fraction, e.g. wood etc.) floats in the suspension or rises to its surface. After the separation of the heavy fraction, a gate valve (111AA350, 112AA350, 113AA350) is opened and the light fraction and suspension flushes into the receptacle of the LRS Screw. The LRS Screw 1/2 (115AT011, 115AT021) removes and transports the light fraction to the Light Fraction Press 1/2 (118AK011, 118AK021) to reduce the moisture content. The dewatered light fraction is taken to the Light Fraction Containers 1 and 2 (115BB101, 115BB102) by the Light Fraction Conveyors 1 and 2 (115AF001, 115AF002). The resulting press water, as well as the excess water at the LRS Screw is guided by a drainage system to the Bow Sieve Drain (116AT001) - where any solids left in the water are removed - and collected on the Pulper Sump PW 0 (116BB001), from where it is pumped back into the Pulpers by the Pulper Sump Pump (116AP001).

Finally, a new cycle can start. Processing time of each batch-cycle depends very much on the type of waste and its composition. In general approx. 60 min for the BTA Waste Pulper with LRS Screw can be assumed.

3.2.1 BTA® Grit Removal System (GRS)

The pulp withdrawn from the Pulper still has a content of heavy fraction particles up to a size of the screen perforation (grit).

First the pulp is pumped into the GRS Tank 1 (120BB001). The pulp is withdrawn out of the coned point of the surge tank and is pumped through the Grit Removal System 121AT001 by the GRS Pump 1 (121AP001) (see Figure 5). The Grit Removal System mainly consists of a hydrocyclone, a classifying pipe, and a gritbox. Caused by centrifugal forces in the hydrocyclone a sludge enriched with grit is discharged as underflow into the classifying pipe and sediments downwards into the gritbox by occurring a reduction of the content of discharged organics due to a weak counterflow with upstream water (through automatic ball valve 121AA305). The gritbox is emptied automatically depending on demand (full gritbox is detected by Level Sensor 121CL301). The operating principle of all Grit Removal Systems (GRS 1 to 4; 121AT001, 122AT001, 123AT001, 124AT001) is identical; however each GRS has a different task within the cascade of Grit Removal Systems: GRS 1 takes primarily the suspension from GRS Tank 1 (120BB001) and transfers it into GRS Tank 2 (120BB002). The remaining time, GRS 1 treats the suspension in GRS Tank 2, taking it from the bottom outlet and putting it back on the top. The main task of GRS 2 (122AT001) is to cyclone the suspension through GRS Tank 2, however it can also take the suspension from GRS Tank 1 in case GRS 1 needs support with this function. The suspension is then transferred from GRS Tank 2 to GRS Tank 3 (120BB003) by the GRS Transfer Pump (120AP001). The Suspension in GRS Tank 3 is treated by the Grit Removal System 3 and 4 (123AT001, 124AT001). The suspension is circulated through each Grit Removal System for several times. On completion of the grit removal cycle, it is transferred to the Buffer Tank Thickener (231BB001) by the Transfer Pump 1/2 Suspension (120AP002, 120AP003).

Identical to the heavy fraction coming from the Pulpers, also the grit is dewatered in a grit classifier (Grit Screw 1/2; 120AT001, 120AT002) and transported to the Heavy Fraction Containers 1/2. The excess water is cought in the drainage and collected in the Pulper Sump Pw 0 for reutilization in the process as Process Water 0.

Fig. 4.6: a) Grit Removal System at Granollers, Spain b) Grit classifier at Mühlheim, Germany

3.3 Thickening step

The organic suspension leaving the hydromechanical pre-treatment has a TS content of approx. 6-8%, as with the removal of the impurities the TS content of the organic suspension decreases.

In order to reduce the hydraulic amount and to have more solids concentration in the organic suspension going to digestion, the organic suspension undergoes a thickening step to increase the TS

content up to approx. 10 - 12%. By this way, also the TS content of the organic suspension entering the digesters can be regulated in a better way.

Due to the large distance between the location for the MT Plant and the location for the AD Plant, the thickening step will be located at the AD Plant (dewatering building) in order to avoid having to pump the thickened suspension over such a large distance.

The organic suspension produced in the MT Plant will be pumped by the Transfer Pump 1/2 Suspension (120AP002, 120AP003) to the Buffer Tank Thickener (231BB001). This Buffer serves as a reservoir for the Feeding Pump Thickener 1 – 4 (231AP001, 231AP002, 231AP003, 231AP004), which feed the Thickeners 1 – 4 (231AT001, 231AT002, 231AT003, 231AT004). The sludge of each two Thickeners is collected in the Sludge Hopper 1/2 (213BB011, 231BB012) from where it is transferred to the suspension buffer by the Feeding Pump 1/2 Suspension Buffer (231AP005, 231AP006). The filtrate from the Thickeners is collected in the Process Water 0 Buffer (232BB001), from where it is transferred back to the AD Plant by the Transfer Pump PW 0 (232AP001) for further use in the Hydromechanical Pre-treatment. The Transfer Pump PW 0 can be used to recirculate the Water in Process Water 0 Buffer and the Feeding Pump Thickener 1 can be used to recirculate the Suspension in the Buffer Tank Thickener.

The thickening step can be bypassed, allowing a direct feeding of the Suspension Buffer (235BB001) with the Transfer Pump 1/2 Suspension.

Fig. 4.10: Thickener units in Valorlis, Portugal

3.4 Reception of cattle manure and poultry dung

3.4.1 Reception of cattle manure

The cattle manure will be delivered by tank trucks and will be discharged within the reception separate reception hall for the agricultural residues located at the site of the AD plant.

The tank trucks will be connected to a quick coupling system. A macerator-pump system (201AJ001 and 201AP001) will pump the content of the trucks to the Liquid Manure Buffer (201BB002). The macerator shall cut the coarse content in the cattle manure to particles smaller than 15 mm. It is understood that the manure does not present impurities but the usual ones to be expected within cattle manure (e.g. straw).

The Liquid Manure Buffer (201BB002) is equipped with a central stirrer (201AT002) to avoid the formation of scum layers or sedimentation layers. Furthermore, the stirrer can be supported by recirculation of the liquid manure with the GRS Pump Manure (201AP002) (see further below).

The liquid manure will be pumped to the Suspension Buffer with a rotary lobe pump, the Manure Discharge Pump (201AP003).

The Liquid Manure Buffer (201BB002) is connected to the exhaust air treatment system from the AD Plant.

3.4.2 Reception of poultry dung

The poultry dung can then be fed to the pre-treatment system with the help of a front loader. For this, the manure solids are discharged at an underfloor hopper (Reception Hopper Poultry Dung, 201AW061) with a chain scraper conveyor with a milling head (201AM061, 201AM062, 201AM063) as dosing unit to the further pre-treatment of the poultry dung.

It shall be noted that poultry dung is a strong source of odours, reason why the laying time in the flat bunker should be reduced to a minimum. For this reason, the presented concept allows as well the direct discharge of the poultry dung at the Reception Hopper Poultry Dung.

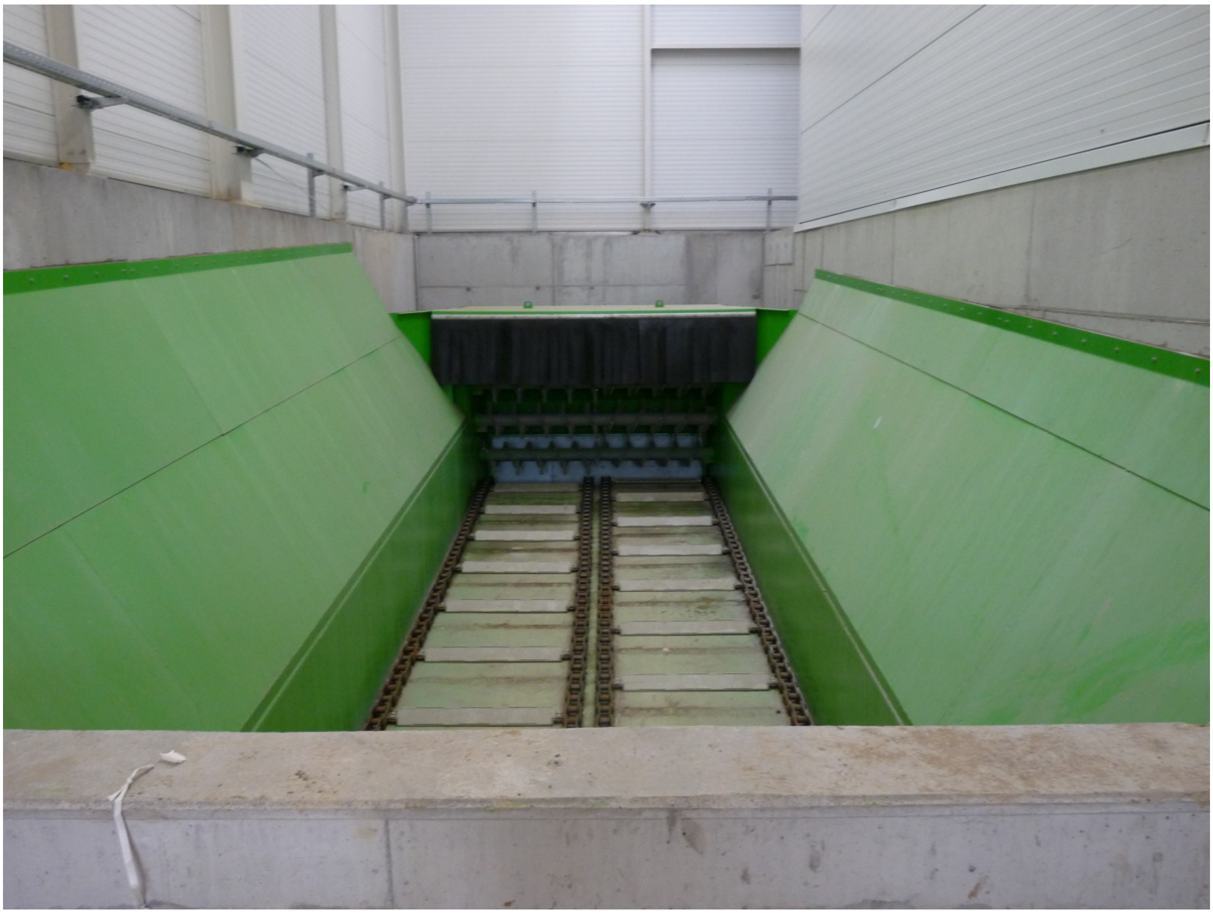


Fig. 4.11: Poultry dung reception hopper

The milling head doses the material to the Mixing Tank Manure (201BB001), where it is mixed with Process Water 1 recovered from the solid-liquid separation.

Considering an average TS content of the poultry dung of 36%, approx. 3,5 times as much Process Water 1 are needed to adjust a TS content of approx. 9,5%. Thus, the daily amount of organic suspension from poultry dung is about 50 m³ (in case of a TS of 46%, approx. 60 m³).

The concept considers daily four mixing and pre-treatment batches at the Mixing Tank, therefore at each batch approx. 12 m³ of organic suspension from poultry dung are obtained. In the above mentioned case of a TS content of 46%, five daily batches will be foreseen.

The Mixing Tank Poultry Dung is equipped with a strong central stirrer (201AT001).

<u>Removal of impurities</u>

It shall be noted that in the tender no indications were made about the content of impurities (grit) in the poultry dung as well as no indications were made regarding the need to remove these impurities before feeding the blended poultry dung to the anaerobic digestion step.

According to our experience poultry dung presents a considerable amount of sand, etc. For this reason in our balance we assume to remove approximately 250 tons/year of grit, which must be removed to avoid its sedimentation in the reactors in the digestion step.

For this reason, a fifth BTA® Grit Removal System will be implemented in the reception hall in the AD Plant (202AT001). The Mixing Tank Manure (201BB001) itself will act as buffer tank for the BTA® Grit Removal System, so that no separate buffer is necessary, and the organic suspension will be recirculated with the help of the GRS Pump Manure (201AP002).

At the end of the batch, the cleaned organic suspension is pumped with the GRS Pump Manure (201AP002) to the Manure Discharge Pump (201AP003), feeding it at the top of the Liquid Manure Buffer (201BB002). Furthermore, during the time the GRS Pump Manure (201AP002) is not used for the GRS batches, it can be used to recirculate the liquid manure to support the central stirrer mixer in the homogenization of the liquid manure in the tanks.

3.5 Anaerobic Digestion

3.5.1 Suspension buffer

In order to obtain a satisfactory digesting operation and the best biogas yield, both in terms of quality and quantity, it is essential that the anaerobic digestion process operates under steady conditions, reducing the fluctuations in the biogas production. In order to achieve this feed regime, and with an intermittent feeding source of pulp from the hydromechanical pre-treatment, a suspension buffer tank (235BB001) is required to provide sufficient feedstock during a 24 hours a day and 7 days a week operation.

Furthermore, in the Suspension Buffer (235BB001) the three streams i) organic suspension from the Organic Fraction of MSW, ii) cattle manure and iii) organic suspension from poultry dung are mixed.

To obtain proper mixing, air from the tank headspace is led after extraction of its condensate in the Condensate Trap SB (235BB003) to the Air Compressor Suspension Buffer , where it is compressed and injected back to the Suspension Buffer via a central gas lance system at the bottom of the tank (235AM001). This induces a proper mixing of the tank contents. Therefore this mixing system does not make use of any mechanical moving parts such as stirrers / mixers / agitators - thus doing away

with mechanical breakdowns of drives, shafts, blades etc., whilst ensuring homogenous mixing within the tank.

Bacterial hydrolysis will commence and consume oxygen, so a certain level of oxygen must be maintained in the injected air, by permitting a very carefully controlled rate of fresh air to the compressor suction, which will suppress methane and odour compounds formation. This introduction of fresh air will be supported by an Inline Blower (235AN003).

The Suspension Buffer is connected to the waste air treatment system in order to abolish possible bad odours.

The condensate collected in the Condensate Trap SB is led to the Condensate Drain 1 (245BB002).

As security measure an overflow tank (Overflow Tank SB, 235BB002) is foreseen.

Both the Condensate Trap Suspension Buffer as well as the overflow tank can be charged up with service water.

3.5.2 Digester

The pulp is pumped from the suspension buffer to two digesters of 4.500 m³ (241BB001, 242BB001), where the biogas production will take place.

The digesters are fed with the means of two eccentric screw pumps (Digester Feeding Pump 1, 241AP001 and Digester Feeding Pump 2, 242AP001). The feeding pipes are interconnected, enabling each digester feeding pump to feed each digesters.

The feeding process of the digesters will be automatic and semi-continuously. It will be fed throughout a twenty-four hour day, seven days a week, for short periods and in frequent intervals by the use of pumps, optimal for the transport of low flowing suspensions containing solids.

The digester itself is a completely mixed reactor. Continuous, sufficient mixing of the digester is very important and has mainly three aims:

- Transportation of initial and reaction products to the biomass (bacteria) to allow a maximum degradation of the organic matter. This degases the biomass and maintains constant conditions of temperature and chemical properties inside the digester.
- Create a strong surface current to avoid the build-up of a scum layer or to destroy a floating scum layer as promptly as possible.
- Avoid biomass and organic solids sedimentation, which will cause “dead zones” in the digester and thereby mechanical problems to extract the digested biomass.

Fig. 4.12: Suspension buffer and anaerobic digester in Granollers, Spain

In order to achieve these goals with maximum performance, mixing with compressed biogas has proven to be a perfect solution.

Part of the biogas produced in the digesters is led to the gas compressors (Gas Compressor 1, 241AN001 and Gas Compressor 2, 242AN001) where it is compressed and pushed back into the digester via a central gas lance system (241AM001 and 242AM001) at the digester's bottom. The biogas creates bubbles while leaving the gas lances and it rises to the liquid level at the top of the digester. Thus, a tremendous amount of liquid is moved – mammoth pump effect – and creates a high velocity current in the central part of the digester up to the surface. It continues horizontally towards the perimeter of the digester, moves down close to the wall region to the bottom and then back to the digester's centre. This big wave has the capability of mixing all the digester's volume. The high surface velocities avoid the formation of scum layers or floating debris in this region.

Fig. 4.13: Scheme of gas lances from gas mixing system

The two gas compressors can be arranged in such a way that one compressor can serve respectively the two digesters of the same size, if necessary, allowing for a certain temporary redundancy.

The advantages of a mixing system with gas lances are:

- **Full mixing leads to a full homogenisation of the suspension in the digester**
- **No mechanical (movable) parts within the digester**
- **Maintenance (e.g. unblocking of a gas lance) can be done from outside**

The temperature of the digester is monitored and maintained by an external recirculation heat exchanger system provided for each digester (241AH001, 242AH001). The organic suspension from the digesters is pumped by the Circulation Pump 1 (241AP002) and Circulation Pump 2 (242AP002) through the heat exchangers where it is heated up by the warm water coming from the CHP unit.

The biological process operates at mesosphilic temperature conditions, i.e. between 36°C and 38°C, which gives considerably higher operating and disposal safety within the process.

Fig. 4.14: External heat exchangers, Valorlis, Portugal

The digesters are equipped with all corresponding safety fittings (e.g. under-/over-pressure valves 241AA451, 242AA451). Furthermore, as security measure an overflow tank is foreseen for each digester (241BB002, 242BB002). Finally, the tank area is surrounded by retention basin.

3.5.3 Aerobisation stage

For the maturation of the digestate, three aeration tanks are foreseen. From the two digesters, the digestate will flow by gravity to the three Aeration Tanks (248BB011, 248BB021, 248BB031), controlled automatically be the valves 248AA311, 248AA321 and 248AA331. Each tank is equipped with an agitator (248AM011, 248AM021, 248AM031) and the required oxygen will be supplied through designated Air Compressors (Air Compressor Aeration Tank, 248AN041, 248AN051, 248AN061).

It is expected that the processes can be exotherm, thus temperature inside the tanks would rise. Therefore, a cooling circuit connected to a chiller (248AH071) to keep the temperature constant are foreseen in order to reduce the potential of foam production as well as to guarantee an efficient solid-liquid separation step (higher temperatures reduce the performance of the polymers).

Furthermore, a separate antifoaming unit (240BB001) will be foreseen for the aeration tanks.

The exhaust air from the aeration tanks is connected to an acid scrubber in order to wash out the high levels of ammonia expected before the air is treated in the biofilter of the AD Plant.

3.6 Biogas treatment

3.6.1 Biological desulphurization

The CHP units provided can burn Biogas with a H2S content of up to 900ppm, though its combustion has a very poor quality. Over this value, the combustion process becomes too rough for proper CHP operation and the engines may shut down.

Towards keeping the engines operational costs as low as possible a maximum figure of 190 ppm of H2S has to be reached, this only being possible through a desulphurization process. The Biogas that actually gets out of the digesters comes with a H2S content of more than 500 ppm and leaves the desulphurization unit with less than 150ppm so that the engines can have the lowest operational costs possible.

From our experience, the risk of high levels of H2S is given with high paper (especially tissue) contents in the MSW, and will primarily be observed for long retention times in the digester (therefore expectable for the start-up time) as well as due to an insufficient mixing of the digester.

Hydrogen sulphide (H2S) needs to be removed from the biogas produced in order to avoid corrosion and to reduce SO2/SO3 levels when the biogas is valorised in the CHP units. In order to ensure H2S concentrations below 180 ppm (as usually requested by suppliers of CHP units), the systems described below will be foreseen.

The external desulphurisation [280AT001] is dimensioned to treat up to 750 Nm^3/hour at a maximum of 2.200 ppm, corresponding to the expected maximum flow rate being also higher than the 698Nm3/h nominal foreseen in the peak scenario.The advantages of external biological desulphurisation plants against other processes such as activated carbon filters or chemical washers are:

- **No use of chemicals (NaOH, H2O2) or iron (FeCl3) and therefore reduced operation costs as well as no danger of corrosion (as given when adding FeCl3).**
- **Continuous operating mode**
- **No disposal costs for active carbon or iron ore**

The bio bed reactor plant is inoculated with selected micro-organisms which are immobilised on the filling material within. It is delivered and assembled together with a container made of polypropylene with a flat bottom and a cone roof. A grate made of synthetic material is integrated into the container. The filling material is inside it. The micro organism suspension is pumped into the circulation and the H_2S dissolved into it. The pump is made of polypropylene. Micro-organisms of the Thiobacillus (e.g. Thiooxidans) type are used.

These bacteria are chemolithotrophs and use carbon dioxide as their carbon source. Their metabolism degradation can be represented generally by the following equations:

H2S + 2 O2 → H2SO4

2 H2S + O2 → 2 S + 2 H2O

S + H2O + 1,5 O2 → H2SO4

As can be seen for this reaction oxygen is required. This could be provided by adding air to the biogas.

Fig. 4.14: External Biological desulphurization

This type of desulphurization has already been employed in a very large amount of anaerobic digestion plants worldwide.

3.6.2 Gas holder

The biogas produced in the digesters will be stored in a 1000 Nm³ gasholder, with 2 membrane system for mesophilic anaerobic process. The storage volume of the gasholder allows to store about 1 hour and 30 minutes of continuous biogas production. This storage time is enough for situations when the engines stop due to electric supply failure or need for minor equipment replacements.

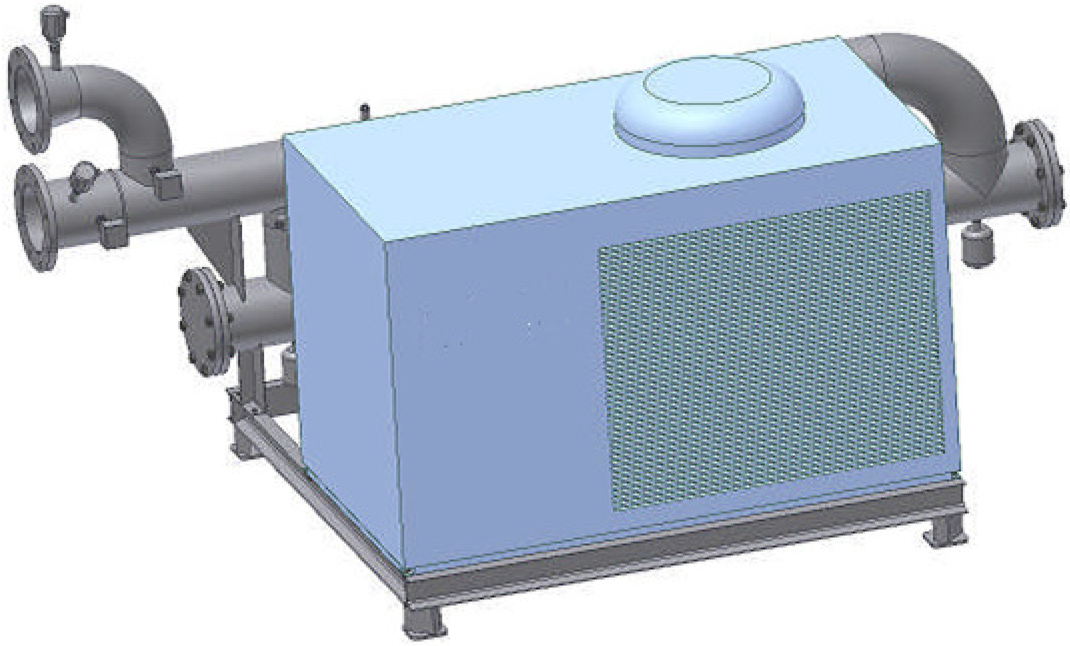
This gasholder has a security system consisting of anti-return valves, safety valves and a ventilation system that ensures its proper functioning. A level sensor (4-20mA) will be installed to allow the control of the amount of biogas available inside it for burning.

After the desulphurization tower the biogas is forwarded to the gasholder, and a minimum pressure of 5mbar for opening the membrane is required. Note that the pressure provided to the input of gasholder is 10-15mbar, as detailed in the previous paragraph.

For maintenance or withdrawal from service a by-pass will be made to gasholder.

3.6.3 Biogas Dehumidification Unit – Biogas Dyer

After the desulphurization of the Biogas to values of less than 150ppm the Biogas can be fed to the CHP units. However, its moisture content has to be reduced and to do so, a dehumidification unit is needed.



The main characteristics considered in the design are:

Biogas throughput

800Nm3/h

Biogas inlet temperature

40ºC

Biogas exit temperature

20ºC

Pressure loss

15mbar

The biogas is fed to the inlet of this equipment and is cooled by the already cooled Biogas that is going out of the Biogas dryer. This reheating and that pre cools the incoming Biogas allows to cool down the incoming Biogas (even though it may not dehumidify it) and thus to save energy costs in the cooling process. The energy exchange takes place in a gas to gas heat exchanger.

After the pre cooling the pre cooled Biogas will get into a heat exchanger where it will be further cooled (and necessarily dehumidified at this stage) by chilled water. This chilled water is fed to the heat exchanger at about 7ºC and further heats to about 15ºC in this Biogas cooling process.

For chill the water, a water chiller is supplied as being part of the unit. This is an air cooled chiller in which the refrigerant used is R407C.

The Biogas dehumidification shall only take place when the Biogas is being supplied to the CHP units.

3.6.4 Biogas Compressor

After the biogas dryer it will be installed two compressors with the capacity to elevate the pressure of the biogas from approximately 5mbar to approximately 110 mbar and a maximum flow rate of 750Nm3/h. Note that the compressor are redundant. The compressors will be responsible for providing pressure and flow needed to operate the engines and flare, so even in the absence of external power scenario the compressors will operate, since they will be fed by means of emergency group. To protect the system and compressors the biogas line will have installed pressure sensors before and after the compressor, to confine the operation of the compressor within a given range of pressure.

3.6.5 Biogas Measurement

The biogas produced in the digesters is continuously measured by a thermal mass flow meter, so that it is possible to totalize the biogas:

Supplied to the flare (Range 0 -750Nm^3/h);

Supplied to the engines (Range 0 -750Nm^3/h);

3.6.6 CHP Units

Based on the nominal amount of biogas expected in a peak scenario, 698Nm3/h, we need to have an installed capacity which is given by the following formula:

PCI (CH4 = 58%) x Flow x electric efficiency = 5, 8 x 698 x 0,425 = 1720KWe.

Faced with this power level we need to install an engine with 1200kW and other engine with 600kW.

The technical characteristics of the engines are:

CHP 1200KW		
Item	Item	Item
Type		V a 60º
Number of cylinders		12
Rotation direction		Anti clockwise
Strokes		4 strokes
Start up system		Electrical
Bore	mm	170
Stroke	mm	195
Rotation Speed	RPM	1500
Unitary displacement	l	4,426
Total displacement	l	53,11
Compression ratio		13,5
Medium efective pressure	bar	14,6
Methane Number		> 70
Lower calofic value	kWh/Nm^3	4
Electrical Power	kW	1200
Fuel consumption	kW	2857
HT energy recovery	kW	636
Heat dissipated in the inter-cooling of the air/biogas mixture	kW	95
Useful Heat	kW	1255
Total exhaust flow rate	kg/h	6458
Air flow rate	kg/h	5947
Exhaust gases temperature	ºC	443
Inlet HT circuit temperature	ºC	80
Outlet HT circuit temperature	ºC	93
HT circuit flow rate	m^3/h	58
Inlet LT circuit temperature	ºC	40
LT circuit flow rate	m^3/h	35
Oil consumption	g/kWh	0,2
Electrical efficiency	%	42,5%

CHP TCG 600KW		
Item	Unit	Value
Type		V at 60º
Number of cylinders		12
Rotation direction		Anti clockwise
Strokes		4 strokes
Start up system		Electrical
Bore	mm	132
Stroke	mm	160
Rotation Speed	RPM	1500
Unitary displacement	l	2,1875
Total displacement	l	26,25
Compression ratio		15,0
Medium efective pressure	bar	16,9
Methane Number		>70
Lower calofic value	kWh/Nm^3	4
Electrical Power	kW	600
Fuel consumption	kW	1412
HT energy recovery	kW	305
Heat dissipated in the intercooling of the air/biogas mixture	kW	38
Useful Heat	kW	608
Total exhaust flow rate	kg/h	3224
Air flow rate	kg/h	2972
Exhaust gases temperature	ºC	447

Inlet HT circuit temperature	ºC	78
Outlet HT circuit temperature	ºC	88
HT circuit flow rate	m^3/h	40
Inlet LT circuit temperature	ºC	40
LT circuit flow rate	m^3/h	10
Oil consumption	g/kWh	0,2
Electrical efficiency	%	42,5

Note: The height of the container with the engines plus chimneys of both CHP is 10m above ground level.

It should be noted that the minimum pressure of biogas that allows operation of the engines is 80 mbar well as the minimum power rating of each motor is 30%.

The engines will be a cogeneration plant as the water from the High Temperature circuit shall be recovered through heat exchangers installed within the engines containers by a recovering system that uses 3 way control valves and a plate and frame heat exchanger.

Both the digesters and desulphurization tower need thermal energy that shall be supplied with this hot water recovered through the CHP units HT circuit.

We then have a thermal power available from 912KWT/h (peak scenario) and the thermal needs for the digesters and the desulphurization tower only 513KWT/h.

3.6.7 Emergency Flare

The emergency flare operates only at the following situations:

- Plant "start up" (to be understood this start up includes the time between the plant actual start up and Biogas production close to nominal conditions)
- Maintenance/damage of one of the CHP units

The emergency flare provided should have a throughput of about 750Nm3/h of Biogas and their characteristics are as follows:

Suitable for gasholder operation

Equipped with a modulating valve

- Maximum flow rate
  - 750Nm3/h
- Minimum flow rate
  - 100Nm3/h
- Minimum CH_4 content
  - 50% (in volume)
- Maximum CH_4 content
  - 75% (in volume)
- Maximum O_2 concentration
  - 4% (in volume)
- Flare arrester according EN standards (ATEX) housing of carbon steel and element of stainless steel
- Height of the flare
  - 8m above ground level

PRINCIPLE OF OPERATION OF THE INSTALLATION (ENGINES PLUS FLARE)

- A single biogas blower (as stated before there is a second one on a standby basis, that starts if the flow switch gives an alarm) will blow the biogas from the gasholder to the three (3) possible consumers, namely both engines and the emergency flare.
- The order for the engines to start up will come from the level sensor installed in the gasholder.

When 500Nm3 (adjustable) are inside the gasholder, one of the engines and one of the blowers, will startup, with the engine operating at full load or as close to it as technically possible. The blower will have a variable speed, modulated by the PLC and through a Variable Frequency Drive, in order to keep the setpoint (110mbar) of the pressure sensor located downstream of the blowers and upstream of the engine.

The flare will be available, but on a standby basis, being in the “ready” mode. A digital signal shall be sent, from the PLC of the flare PLC to the installation PLC proving the flare. The installation PLC will provide to the flare the ready to run (in the “ready” mode).

The pressure transmitter must be wired directly to the flare control panel, in order for PLC of the installation to be able to control the speed of the blower. The flare is required to send to the PLC of the installation a 4-20mA signal of the Biogas pressure in the piping. This analog signal is sent to the installation PLC regardless the flare is in operation or not, once the PLC needs this signal to be able to modulate the blower speed through its VDF.

- As the level within the gasholder reaches 750Nm3 (adjustable), the second engine starts up, and just like the first engine, it is placed at full load or as close to it as possible. Again, the pressure in the piping is maintained constant by controlling the frequency of the blowers (through a VFD).
- Regardless of the number of engine running and the engines load, the Biogas pressure within the piping will be maintained constant, by modulating the blower speed through its Variable Frequency Drive.
- The amount of biogas blown by the blower, and therefore, drawn by the engines will be purely and solely modulated by the engines throttle valve and by the engines step motor, at the engines biogas mixer.
- As the load of the engines varies (if such is required for knocking reasons, for instance), so will, of course, the biogas flow rate drawn into the engines vary.

This will be made at the expense of light variations of the pressure upstream the engines Biogas train, which will be immediately compensated by varying the speed of the blower, so that the pressure setpoint in the piping is restored.

For instance, when the engines decrease their load, the biogas consumed will decrease which will tend to increase the pressure in the piping upstream. The consequence will be a reduction in the blower speed, in order to re-establish the pressure within the Biogas piping. Conversely, if the engines load increases, the biogas flow rate to the engines increases and thus the pressure in the biogas piping will decrease. The blower will compensate this by increasing its speed, restoring once again the pressure in the biogas piping.

- Once the level within the gas storage tank reaches 950m3, as sensed by the storage tank level sensor, your flare is commanded to start, though a start signal that will be sent by our PLC, as it is Efacec PLC which monitors the level in the Biogas storage tank.

The sequence of operation for the starting up of the flare must be as follows:

1. The pilot line solenoid valve is opened;
2. A spark is generated in order to ignite the biogas (biogas and air) that gets out of the pilot line;
3. The two steps above are repeated (a given number of times), if necessary, until the pilot flame is detected, as sensed by the UV sensor;
4. After pilot flame is proven, the flame is stabilized for, say, 20s or so;
5. After the pilot flame has been stabilized for about 20s, the Slam Shutoff Valve (SSV) is commanded to open;
6. The SSV is recognized fully open upon the flare PLC has received a digital signal from an end switch at the valve actuator. This proves the SSV is fully opened;

To be noted that between the moment the flare has received the start signal until this moment, where the SSV is fully opened, which may take more than one minute depending upon there is some problem with igniting the pilot mixture, the pressure control is still being done by the blowers variable speed, which means that Efacec PLC is still controlling the pressure in the piping.

1. Then, after the SSV valve is proven open by the end switch, the flare PLC must send a digital signal to Efacec PLC proving the flare is ready to run and ready to take over control of the pressure in the piping.
2. As the flare PLC sends the signal stating it is ready to run and that it will take over the pressure control of the biogas pressure in the piping, our (Efacec) PLC will ramp up the blowers on a time frame of around 30s. At the same time, the flare, already in control of the pressure, will module the control valve open as required, in order to maintain the exact same setpoint of the static pressure sensor as the blower ramps up.

3. After the blower has reached its full speed, the pressure control will continue to be performed by the flare modulating valve.
4. This is the same as saying:
5. If one engine shuts down or reduces its load while the flare is running, the flare modulating valve will open as required to maintain the pressure setopoint in the piping, as sensed by the pressure sensor.
6. If the engine that has shutdown or that has seen its load reduced is put back into operation or if it is allowed to increase its load, the flare modulating will modulate closed as required to maintain the pressure setpoint in the piping.

To be noted that once the blower has reached its full speed, the biogas flow rate that will be blown by the blower will be 750Nm3/h, with a constant pressure fed to the engines of 110mbar. Part of this Biogas will go to the engines, the remaining going into the flare.

The two way modulating valve is required to be installed, as we want to make sure the engines won't starve of Biogas. So, if the pressure in the pipe runout to the engines gets below the pressure set-point, due to too much Biogas being burned in the flare, the 2 way modulating control valve will modulate closed in order to restore the pressure in the pipe runout to the engines. If the pressure in the pipe runout to the engines gets above the pressure setpoint, the valve will modulate opened in order to restore the pressure setpoint in the pipe runout, as already referred above.

If an engine is shutdown while the flare is running (with the level of Biogas within the biogas storage tank above the threshold for which the flare is shutdown), whether for planned or unplanned maintenance or for any other reason, the pressure sensor in the pipe runout to the engines will sense an increase in the biogas pressure and the flare PLC control system will modulate the 2 way control valve opened in order to lower the pressure in the pipe runout to the engines, therefore maintaining the pressure setpoint, the flare burning the surplus Biogas.

When the flare is to be shutdown (Biogas storage tank level sensor detects a level below 800Nm3/h (adjustable), the control strategy is once again to change, this time around from the modulating valve action to varying the blower speed through its VFD. In order for this changing in control to happen, digital information shall be sent, from Efacec PLC to the flare PLC, commanding the flare to shut down. As soon as Efacec PLC sends this shutdown signal to the flare PLC, Efacec PLC takes over the pressure control in the piping, therefore and immediately modulating the speed of the blower as required in order to maintain the pressure transmitter setpoint.

As soon as the flare is commanded to shutdown, and in order not to create a pressure peak in the piping, the 2 way modulating valve will slowly start to close (say on a 30s span), slowly starving the flare with biogas, the pressure in the flare biogas train dropping, at the same time the pressure in the pipe runout to the engines rising. As Efacec PLC is now in control of the Biogas pressure, modulating the blower speed through its VFD, the biogas pressure increase due to the slow closing of the flare modulating control valve is compensated by the decrease in the blower speed through the blowers variable frequency drive, then restoring the pressure in the piping. As the 2 way modulating valve continues to close, less and less biogas is fed to the flare; after the 2 way modulating valve has fully closed, as proven by the end valve actuator end switch, the flare SSV closes immediately and the flare is finally shutdown.

The strategy of slowly closing the 2 way modulating control valve, rather than abruptly closing both the 2 way SSV and 2 way modulating valve, in order to shutdown the flare, shall be done solely to avoid pressure peaks in the pipe system leading to the engines, as would otherwise happen should the SSV closed “instantaneously”.

3.7 Dewatering

3.7.1 Centrifuges

The aim of the solid-liquid separation is to divide the digested biomass (digestate) into a thin liquid fraction with low total solids content (approx. 1,5-2% - centrate) and a solid fraction with high total solids content (approx. 30%).

This will be achieved by three centrifuges. Centrifuge 1 and 2 (251AT001, 252AT001) will be fed by the Feeding Pump Centrifuge 1 and 2 (251AP001, 252AP001) with digestate from each aeration Tank. The third centrifuge (235AT001) will be feed by the Feeding Pump Centrifuge 3 (235AT003) with Process Water coming from Process Water Buffer 1 (260BB001). The feeding pipes are interconnected so that it is possible to feed any centrifuge with any of the three feeding pumps. The same applies for the Dosing Pumps FHM (251AP002, 252AP002), which can deliver the Polymer solution from the Flocculant Station (254BB001) to any of the centrifuges.

Fig. 4.14: Centrifuges from Flottweg specially developped for similar purposes ;
centrifuges from Flottweg at Kirchstockach, Germany

3.7.2 Storage Dewatered Digestate

The dewatered digestate falls from the centrifuges down on a belt conveyor (250AF001) which transports it to a flat bunker beside the composting hall.

3.8 Process Water Management

The Process of Hydromechanical Pre-treatment, the dewatering of the Suspension as well as various other points and devices in the process require a certain amount of Process Water, which is produced internally in the following way:

As a “starting point”, the centrate from the centrifuges 1 and 2 is fed to the Bow Sieve Centrifuges (255AT001), where fibrous solids, plastic flitters and similar particles are removed and collected in the sludge container (255BB001). The water which passes the Bow Sieve is collected in the Centrate Buffer (250BB001), from where it is pumped by the Centrate Discharge Pump (250AP001) into the Process Water Buffer 1 (260BB001). The Centrifuge 3 now takes the water from Process Water Buffer 1 (see chapter 4.8.1) in order to remove even more solids. The centrate from Centrifuge 3 is collected in the Process Water 2 Pump Pit 1 (250BB002), from where it is pumped by Process Water 2 Pump 1 (250AP002) into the Process Water 2 Buffer (262BB001). From there, the Process Water 2 Pump 2 (262AP001) fills the Process Water 2 Pump Pit 2 (262BB002), which again serves as a reservoir for the Pressure Increase Pump AD (262AP002). This pressure pump fills the Pressurization Tank PW2 AD (262BB003), creating a high pressure level, so that the process water can now be used for the various consumers in the process (Thickeners, Centrifuges, Manure Reception).

The process water supply of the MT Plant begins with the Process Water 1 Transfer Pump (260AP001), which pumps water from Process Water Buffer 1 (260BB001) in the AD Plant to Process Water 1 Buffer MT (160BB001) in the MT Plant. From there, the water is pumped onto the Micro Strainer MT (161AT001), where further solids are removed, by the Micro Strainer Feeding Pump (161AP001). The water passing through the Micro Strainer is collected Process Water 2 Buffer MT (162BB001), from where the Pressure Increase Pump MT (162AP001) charges the Pressurization Tank PW2 MT (162BB002) with pressurized water. In this way, the pressurized water is supplied for the various consumers (GRS, Pulpers, LRS,…).

The water used for the dilution of waste in the Pulper and for the rinsing of the LRS is provided in the following way: The filtrate from the Thickeners, which is collected in Process Water Buffer 0 (232BB001) is transferred by Transfer Pump PW 0 (232AP001) to the Pulper Sump PW 0 (116BB001) from where it is used in the Pulpers (see chapter 4.2).

There is also the possibility of replacing Process Water 0 by Process Water 1 in the following way: Process Water 1 can be released from Process Water 1 Buffer MT (160BB001) by free flow through the valve 160AA305. Alternatively, the Process Water 1 Pump MT (160AP001), which is normally used for the rinsing of the LRS, can feed the Pulpers directly with Process Water 1.

To create a further redundancy, the pipes PW_232/50-PE-80 and PW_260/50-PE-200 can be used alternatively for the transfer of PW 0 and PW 1 from the AD Plant to the MT Plant.

3.9 Internal Waste Water Treatment Plant

The surplus water, which has to be treated in the Internal Waste Water Treatment Plant, is fed by the Water Treatment Charge Pump 1 and 2 (265AP001, 267AP001) from the Process Water Buffer 2 (262BB001) to the Nitrification/Denitrification 1 (265BB001) and Nitrification/Denitrification 2 (267BB001). The oxygen required for the process is supplied by the Air Compressor 1, 2 and 3 Waste Water (265AN061, 265AN071, 265AN081) and is introduced through an Air Diffuser System (265AA403, 267AA403). In each Nitrification/Denitrification Tank, two Agitators (265AM001, 265AM002, 267AM001, 267AM002) are installed in order to enhance the biological process.

From the Nitrification/Denitrification Tanks, the water overflows into a Sedimentation Tank (265BB002), where the liquid phase is separated from the biomass and suspended solids still present in the effluent. The sludge settling on the bottom of the tank is pumped back to the Nitrification/denitrification tanks by the Sludge Backcharge Pumps 1 and 2 (265AP041, 267AP041) or is discharge as surplus sludge in the Suspension Buffer by the sludge discharge pump 1 and 2 (265AP002 and 265AP051) (the sludge that sediments along the tank is conveyed into the funnel by means of a Bottom Scraper. The Sedimentation Tank is also provided with a Floating sludge/Foam removal system).

The treatment process requires some auxiliary devices:

- Carbon will be provided by an external source: A Dosing System for Acetic Acid, consisting of Acetic Acid Dosing Buffer (266BB010) and Acetic Acid Dosing Pump 1 and 2 (266AP011, 266AP021).
- Phosphorous is removed by dosing a precipitation agent (e.g. FeCl3) into the Nitrification/denitrification Tanks. It will be provided by a Dosing System for Ferric Chloride, consisting of Ferric Chloride Dosing Buffer (266BB041) and Ferric Chloride / Alu-Chloride Pump 1 and 2 (266AP041, 266AP042).
- Dosing of an Antifoam Agent might become necessary at times. It will be provided by a Dosing System consisting of Antifoamt Agent (266BB031) with Agitator Antifoaming (266AM002) and the Antifoam Dosing Pump 1 and 2 (266AP031, 266AP032).

The treatment process is described in more detail in a separate document.

The final effluent which is produced by the internal Waste Water Treatment Plant is collected in the Pump Receiving Tank (265BB025), from where it is further transferred by the Process Water 3 Pump (265AP031) into the Surplus Water Tank (265BB003). From there it is pumped by the Surplus Water Discharge Pump (265AP061) into trucks and brought out of the plant.

3.10 Ancillaries

3.10.1 Compressed air system

The Compressed Air System is used to drive the pneumatic valves of the process fluid network.

Due to the distance, two compressed air systems will be foreseen: one for the MT Plant and one for the AD Plant.

3.10.2 Auxiliary heating unit

In addition to the heat recovery from the CHP units, a separate heating system (298AX001) is foreseen for the heating of the process, the halls and the administrative building, both for the start-up phase or in case of breakdown from the CHP units.

3.10.3 Hoisting devices

The following hoisting devices will be foreseen:

- For service and maintenance works at the BTA Waste Pulpers a mono-rail crane with a carrying capacity of 3.5 tons for the stirrers will be foreseen which allows to transport them to the laydown area (see layout).
- For service and maintenance works at the dewatering and thickening hall a mono-rail crane with a carrying capacity of 2.5 tons for the bowls of the centrifuges and thickeners will be foreseen which allows to transport them to the laydown area in the ground floor (see layout)

3.10.4 Rain Water and Service Water Facilities

Rain water is used in the process for consumers which need water nearly free from solids. It is collected in the Rainwater Tank 2 Ceilings AD (268BB002) and transferred by the Rainwater Pump 1 (268AP001) into the Pressurisation Tank Service Water AD (268BB003), from where it is released to the consumers (e.g. Flocculant Station, Desulphurization etc.).